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POWER MEASUREMENTS IN ELECTRONIC CIRCUITS

Power measurements can reveal the operating condition of electronic equipment. Useful in developmental procedures, they are also an aid to troubleshooting. These measurements include power drain, power input, and power output checks. Lack of equipment or unfamiliarity with test methods make power the quantity measured least often by electronic technicians.

A laboratory which is well equipped in other respects falls short of adequate instrumentation when no provision is made for power measurements. This article is a review of wattmeters and other power measuring gear, and of power checking methods. The reader is offered a liberal selection of descriptive data from which he may pick an instrument or circuit best suited to his individual requirements.

Basic Relationships: Current, Voltage, Resistance, Power

The elementary relationships between power (P), current (I), voltage (E), and resistance (R) are expressed as follows:

(1) $P = EI$
(2) $P = I^2R$
(3) $P = E^2/R$

In the foregoing relationships, power is expressed in **watts**, voltage in **volts**, current in **amperes**, and resistance in **ohms**. These formulae are entirely correct for d. c. power but can apply without alteration to a. c. *only* when the power consuming device is purely resistive or when the power factor of the load device is equal to 1. In all other cases, the simple formula EI gives **volt-amperes** instead of watts. True a. c. power is obtained by multiplying volt-amperes by the cosine of the phase angle. For example:

(4) $P = EI \cos \theta$

The term cos θ (known as the power factor) is equal to unity for pure resistance loads (0° phase angle) and is some value less than 1 when reactance is present. Thus, in practical cases, true a. c. power is somewhat less than the simple EI product.

Use of Simple Meters

Equations (1), (2), and (3) suggest the use of current meters and voltmeters for power measurement, and this method indeed is practical for checking d. c. power — and also a. c. power in resistive loads. In such cases, the current flowing through a load can be measured with an ammeter and the voltage drop across the load with a voltmeter, and the power in watts determined by means of Equation (1). If the resistance of the power consuming device (load) is known accurately, one of the meters can be omitted. For example, the load current can be squared and multiplied by

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the resistance to obtain watts, by Equation (2). Similarly, the voltage drop across the load may be squared and divided by the resistance, according to Equation (3), to obtain watts.

Operators of radio transmitters regularly determine the d. c. plate input power to vacuum tubes by multiplying the readings of the plate voltmeter and milliammeter. The same technique is employed by audio technicians to determine the d. c. power input to audio power amplifier stages. In the same way, the d. c. input power to transistor electrodes may be computed from the electrode voltage and current.

Two precautions are necessary when using voltmeters and/or ammeters to measure power. First, the ammeter, being a series element, must have low internal resistance to minimize its power consumption in the circuit. Second, the voltmeter, being a shunt element, must have high internal resistance to minimize its current drain.

The accuracy of a. c. power measurements with simple meters is limited at high frequencies by the frequency response of the instruments. For example, voltmeters and ammeters intended for use at power-line frequencies might exhibit considerable error at the higher audio frequencies and would be useless at radio frequencies.

Figure 1 illustrates the three common methods of employing simple meters in power measurements. Some adaptation of one of these methods often is applied in special wattmeters. When it is possible to hold either voltage or current constant, the scale of the other meter may be graduated to read directly in watts. Figure 2

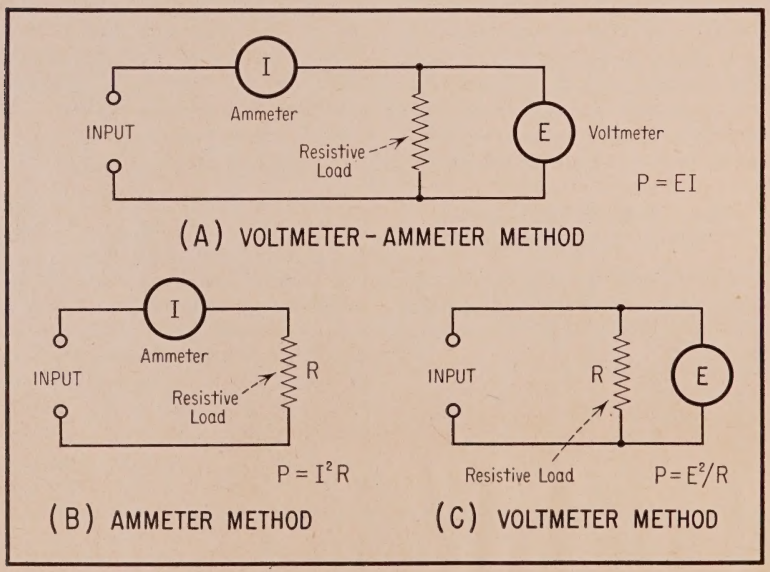


Fig. 1. Measurement of Power with Simple Meters.

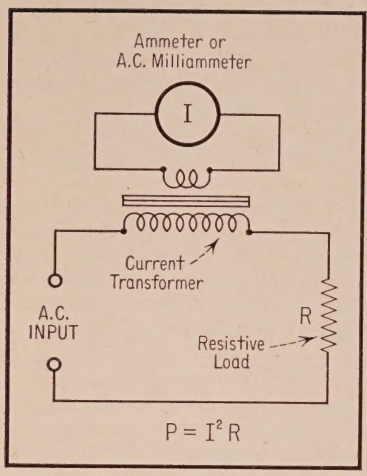


Fig. 2. Current Transformer Coupling in A.C. Power Measurement.

shows a variation of the ammeter method of Figure 1(B) suitable for a. c. power measurements in resistive circuits. Here, a low-range a. c. ammeter or milliammeter is coupled to the power circuit through a suitable current transformer. The meter may be provided with several direct-reading watts scales corresponding to commonly used load (R) values.

Electrodynamometer-Type Wattmeter

The electrodynamometer type of wattmeter is satisfactory for measuring power directly in watts or kilowatts in either a. c. or d. c. circuits with all types of loads.

The basic arrangement of this instrument and its connection into the circuit are shown in Figure 3. The movable element of the meter, to which the pointer is attached, consists of two coils fastened together. One of these is a low-resistance coil through which the load current is passed. This is designated the **current coil** in Figure 3. The second is a high-resistance coil (designated the **potential coil** in Figure 3) which is connected in parallel with the load and accordingly is activated by the load voltage. The meter input terminals may be labelled C-C and V-V, corresponding to the two coils, as shown in Figure 3, although other designations sometimes are employed by meter manufacturers. In this wattmeter, the deflection of the pointer is governed by both current and voltage acting upon the double-coil assembly and is proportional to the product of the two, which is the power in watts.

The illustration shows the left-hand V terminal connected externally to the left-hand C terminal. The potential coil thus appears not to be connected exactly to the top of the load. Actually, it is immaterial whether the left-hand V terminal is connected to the left or right-hand C terminal, since the voltage drop across the current coil is negligible, and the potential coil effectively is across the load in each

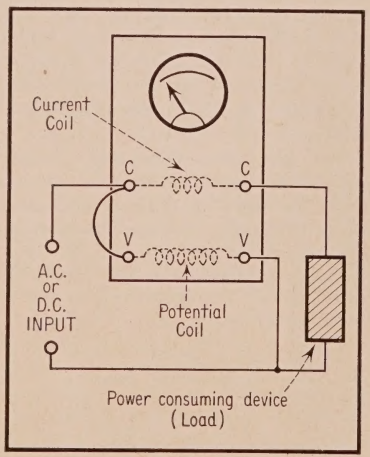


Fig. 3. Electrodynamometer-Type Wattmeter.

case. In some wattmeters, there is no choice in the matter, since the connection is made internally.

Dynamometer-type wattmeters are available in laboratory, small portable, and panel models. Laboratory types are available with full-scale deflections ranging from 75 watts to 60 kilowatts. Their accuracy ratings are as good as ½ per cent. Portable wattmeters of this type commonly are available with a basic 0-100-watt scale which can be multiplied up to 10 kw with an external transformer. A familiar example is the "appliance tester" used by servicemen to check the power drain of radio and TV receivers, motors, refrigerators, and other electrical appliances. Small panel-mounting dynamometer-type wattmeters are obtainable with full-scale deflections ranging from 75 watts to 10 kw and with accuracies as good as 1 per cent.

Wattmeters of the dynamometer type are used almost exclusively to measure power drain of electrical devices. They seldom are employed for power output measurements, largely because of their relatively high current requirements. For this reason, these meters usually are designed for operation at power-line frequencies. Polyphase, as well as single-phase types are available.

The user of a wattmeter must be careful to make the correct connections to the instrument terminals. There is danger, through inattention, of connecting the current coil accidentally across the load. Since the resistance of this coil is quite low, a burnout is apt to occur.

In general, a dynamometer type of instrument is somewhat higher in price than common movable-coil meters of the same size. Wattmeters of this type are a good investment, however, and may be used extensively by the electronic technician. An abnormal power drain, easily spotted with a direct-reading wattmeter, indicates trouble — present or near-future — in a radio or TV. When electrical appliance servicing is pursued as a sideline to electronic work, the wattmeter becomes essential equipment.

Simple Power Drain Meter

In some instances, the infrequency of power drain measurements does not seem to justify an expensive wattmeter. A low-cost means then is desired for checking occasionally the wattage of various electronic devices operated from the power line.

Figure 4 shows a simple adaptor for making such power measurements with an a. c. voltmeter of the service type. The voltmeter should have a sensitivity rating of at least 1000 ohms per volt. The adaptor consists of an accurate 1-ohm power-type resistor mounted in a ventilated housing pro-

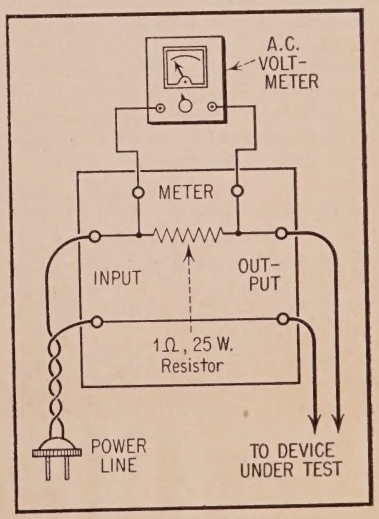


Fig. 4. Power-Drain Adaptor for Voltmeter.

POWER (Watts)	VOLTMETER DEFLECTION (Volts)
75	0.65
100	0.87
150	1.30
200	1.74
250	2.17
300	2.61
350	3.04
400	3.48
450	3.91
500	4.35
Based on 115 Volts Supply	

TABLE 1

vided with terminals for connection to the a. c. line, voltmeter, and power consuming device. Actually, this resistor converts the voltmeter into an a. c. ammeter. At any deflection of the voltmeter, the reading is directly in a. c. amperes. To convert to watts drawn by the load, multiply the deflection by the line voltage value. Table 1 lists voltage readings corresponding to common power levels, based upon a line voltage of 115 v. Power levels lower than 75 watts give deflections too small to be read accurately on conventional service-type a. c. meters. Above 500 watts (top limit of the Table), the voltage drop across a 1-ohm resistor becomes large enough to reduce significantly the voltage applied to the device under test. If higher power levels are to be measured, the resistor should be reduced to 0.5 or 0.25 ohm.

A power drain meter of this type may be constructed in permanent form by internally shunting a simple rectifier-type 1-volt a. c. voltmeter with a 1-ohm 25-watt resistor.

D. C. power drain can be measured by substituting a d. c. voltmeter for the a. c. instrument shown in Figure 4.

Audio Power Output Measurements

The power output of audio amplifiers often must be measured as a routine step in design, adjustment, or troubleshooting. Several methods are available to the technician.

Simple Meter Method. Figure 5 illustrates the conventional methods of employing an a. c. ammeter or high-impedance a. c. voltmeter to determine audio output power. In each case, the amplifier under test is driven by a signal from a low-distortion audio oscillator. The measurement may be repeated at each frequency of interest and at each setting of the volume and tone controls at which power output information is desired.

The output terminals of the amplifier are connected to a resistor having a resistance value equal to the normal load impedance recommended for the amplifier. Thus, a 30-ohm resistor would be substituted for a 30-ohm speaker voice coil ordinarily used with the amplifier. This equivalent load resistor must be rated to dissipate safely at least twice the expected power output of the amplifier.

In Figure 5(A), an a. c. ammeter is connected in series with the load resistor. This meter must have good accuracy up to the highest test frequency which will be employed. The power output (watts) is computed by squaring the current meter reading (amperes) and multiplying this figure by the load resistance (ohms).

In Figure 5(B), an a. c. vacuum-tube voltmeter is connected in parallel with the load resistor. This type of meter is recommended because of its very high input impedance. However, a high-resistance rectifier-type meter (e.g., 5000 ohms per volt) might be used with low values of load resist-

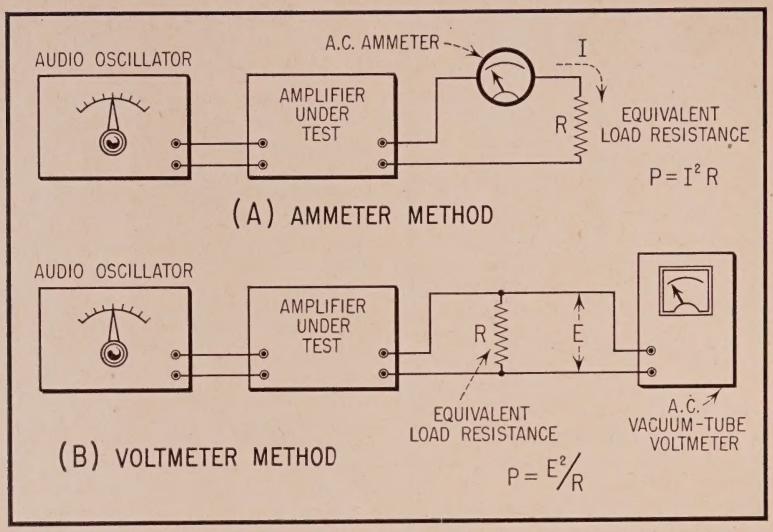


Fig. 5. Checking Audio Power Output with Common Meters.

ance, with negligible loading error. The power output (watts) is computed by squaring the voltmeter reading (volts) and dividing by the load resistance (ohms).

Care should be taken not to overdrive the amplifier with the signal from the oscillator. In this connection, it is advisable to connect an oscilloscope across the load resistor in both test setups shown in Figure 5. The shape of the oscilloscope pattern will apprise the operator immediately when distortion, due to overdriving or other causes, has set in. It is important to adjust the signal input level and the amplifier controls for sinusoidal output, since the meters used for the power determination may exhibit significant waveform error.

Output Power Meter (V. T. Type). The principle illustrated in Figure 5(B) is embodied in several commercial audio output power meters which read directly in watts and are self-contained.

These meters contain a number of load resistors (R) having values corresponding to common amplifier and transmission line impedances and arranged around a selector switch. A set of auxiliary terminals on this switch at the same time select several pre-set calibration resistors which modify operation of the basic v. t. voltmeter circuit in such a way that its scale reading in watts is correct for each value of load R.

The use of this instrument is simple and convenient. The output terminals of the amplifier under test are connected directly to the meter input terminals. The meter impedance switch is set to the recommended load value of the amplifier, and the watts range switch is set to a trial range. The amplifier then is driven by an oscillator signal at the desired frequency,

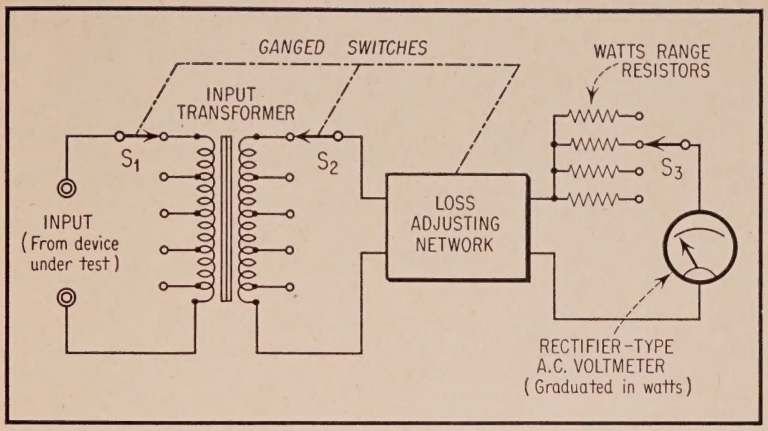


Fig. 6. "Non-Electronic" Audio Output Power Meter.

and the power output read directly on the instrument scale.

Output Power Meter (Non-Electronic Type). A second commercial type of audio output power meter utilizes a rectifier-type meter, instead of a vacuum-tube voltmeter, thereby eliminating the power supply.

A functional skeleton diagram of this type of instrument is shown in Figure 6. The output of the amplifier under test is presented to the input coupling transformer. The latter has a variable ratio selected by the ganged switches S_1 and S_2. This arrangement allows the metering-circuit impedance to be matched to the amplifier output impedance. Also ganged with switches S_1 and S_2 is a variable, resistor network for loss adjustment. Resistance losses in the switched input transformer are compensated by this network.

Multiplier resistors are selected for the rectifier-type a. c. meter by switch S_3. These resistors provide various power ranges. The meter scale is graduated in milliwatts.

The familiar General Radio Type 583-A Output Power Meter employs an arrangement similar to the one shown in Figure 6 and indicates power values from 0.1 mw to 5 watts. It provides forty impedances between 2½ and 20,000 ohms.

R. F. Power Measurements

The power output of radio-frequency sources such as oscillators, exciter stages, and power amplifiers can be checked by methods similar to those described for checking audio power, except that the indicating instruments must be capable of accurate operation at the high frequencies involved.

In using simple instruments, the procedure is to connect a non-inductive power-type matching resistor to the output terminals of the r. f. power source and to measure either the current through this resistor or the voltage drop across it. The power value then is computed, as in audio measurements, by Equation (2) or (3), whichever applies. Special precautions are necessary when making r. f. measurements, however. These include using the shortest possible leads, and shielding the components and meters, at very high frequencies, to minimize bypassing of the r. f. currents.

Dummy Antenna. Figure 7 shows two circuits of the "dummy antenna" type which are used to measure r. f. power output. In each example, the r. f. ammeter is a high-frequency instrument of the thermocouple or crystal diode type. The load resistor must be non-inductive and can be of the plaque type or may be composed of several carbon or composition resistors connected in parallel to handle the power. The resistor must be rated to handle safely at least twice the expected power.

The first circuit, Figure 7(A), is intended for connection directly to the 50-ohm output terminals of a transmitter or exciter. To obtain the power level in watts, square the current meter indication and multiply by 50. If desired, the scale of the meter may be graduated directly in watts according to the relationship: $P = I^2R = 50\ I^2$.

The second circuit, Figure 7(B), is more flexible, since it is adaptable to r. f. sources which do not have the fixed 50-ohm output impedance required by the arrangement in Figure 7(A). Here, the r. f. energy is picked up from the output tank coil of the generator by closely coupling the link pickup coil, L_1, to the "cold" end of the tank coil. In the measurement circuit, coil L_3 is resonated by the variable tuning capacitor, C, to the generator frequency, as indicated by peak deflection of the ammeter. Coil L_3 is closely coupled to the link coil, L_2. The inductance of L_3 is chosen for resonance with capacitor C at the generator frequency.

In this circuit, as in the preceding case, the r. f. power is computed from the relationship: $P = I^2R$.

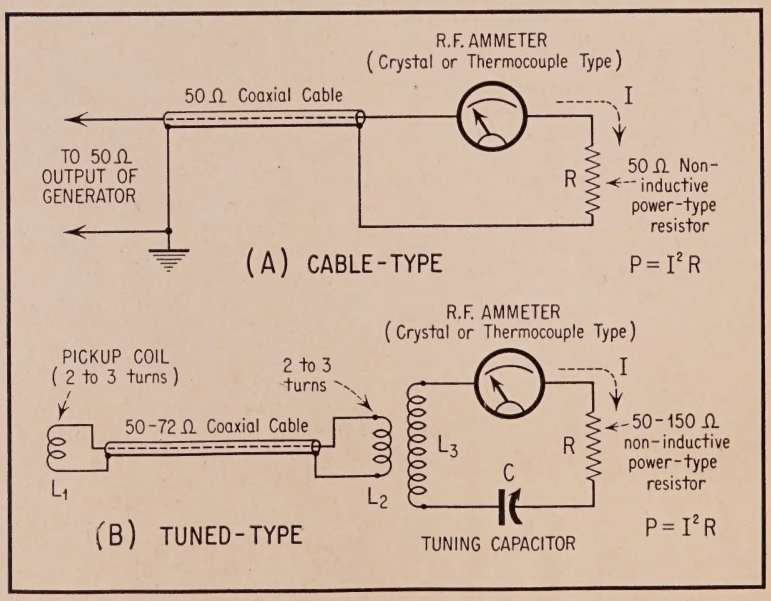
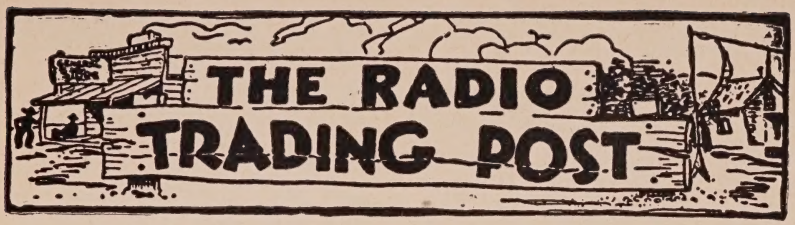


Fig. 7. "Dummy Antenna" Power Measuring Circuits.



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TRADE — 7" Motorola TV set, needs picture tube; for printing press, or what have you? Prefer local contact. V. Lombardo, 1679 Lafayette Avenue, New York 72, N. Y.

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FOR SALE — 522 transmitter converted to 6 v., $20; 522 receiver, partially converted CQ 1947, $10; Gonset 2 meter converter and noise clipper, $30; Eldico TR75 with coils for 80, 40, and 20 M, $40. Sol Herman, c-o Universal-Lipman, Box 191, Jamaica, L. I., N. Y.

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SELL OR TRADE — Two-stage amplifier, TVX Tele-Booster, 6-tube Truetone table model D709, superheterodyne, battery operated in A-1 cond., for tube checker or signal generator. J. Hearn Hill, 1628 South 11th St., Waco, Texas.

SELL OR SWAP — 80 meter, center loaded mobile whip antenna with mount, no spring, good for 10 meters with loading shorted, $5; GE hand vacuum cleaner, $5; code oscillator $2. Want ham crystals, plug-in coils, coax fittings. Box 142-G, Sparta, N. J.

FOR SALE — Motorola auto radio, model KR8 for '47 or '48 Kaiser-Frazer. Make offer. Botbyl Radio Shop, 1009 Sophia, Muskegon, Mich.

FOR SALE — SCR 522 Trans. with tubes, crystals for 2-meter band, and 120 v. AC power supply, $20. Fred Alexander, 40 - 06 Vernon Blvd., Long Island City 1, N. Y.

FOR SALE — RME-69 receiver less spkr., $40; UTC S-49 Xfmr., meters, coils, tubes, prop pitch motor, other ham parts; automobile cylinder hone, $10. All FOB. George Pierce, R 2, Box 50K14, Saint Joseph, Mich.

FOR SALE — Jackson CRO-2 scope in orig carton, $150; 20 w. Masco amp., $15; portable laboratory meters in good cond. O. Hergenhan, 503 South 15th St., Newark 3, N. J.

WANTED — S-38 receiver or others. Will trade '41 Plymouth radio, dual vibrapack 400 v. at 125 Ma., novice transmitter, dynamotor — 6 v. input, 110 v. AC output, Masco 10 w. amplifier. Stan Zuchora, 2748 Mead St., Detroit 12, Mich.

FOR SALE — Simpson 260 in orig. carton, $30; Weston Volt - ohm - milliammeter, model 697, $12; Heathkit grid dipper wired and operating l. n., $20; DN-HZ astatic dynamic mike, $7. I. Seidman, 1535 Longfellow Ave., New York 60, N. Y.

WANTED — Instruction and maintenance manuals for Panadaptor. Frank's TV, 4234 West 90th Place, Oak Lawn 9, Ill.

WANT — Supreme Multitester, model 547. Name your price. Egan Radio Service, 103 S. Main St., Fond du Lac, Wis.

SELL OR TRADE — Precision 920P tube and set tester, $25; Heath 03 scope, $20; Superior 670-A Super meter in original carton, $25. Want Edison hard wax cylinder records. Chester Wegrzynowski, 51 North Central St., Buffalo 12, N. Y.

WANT — Rimco signal tracer, must be in good cond., with all probes intact. State price. Connie Jenkins, 1905 Queen Anne Ave., Seattle 9, Wash.

FOR SALE — Modern Radio-TV service shop in East Bronx, with equip., or truck. No reasonable offer refused. Tru-Vue Electronics, 649 E. 180th St., Bronx 57, N. Y.

SELL OR TRADE — Boehme keyer, $145; Boehme portable ink recorder, $175; SX-42, $145; NC-100-X, $95; Viking I TVI'd, $185; 32V2, $485. Want 75A1, 75A2, 310B, APR-4. Tom Howard, 46 Mt. Vernon St., Boston 8, Mass.

FOR SALE — 10 coin-operated radios with night-stand tables attached in good cond. Best offer over $300; Heathkit BG-1 bar gen., completely assembled, never used, $15. J. O. Turner, Box 37, Homer, Louisiana.

FOR SALE — 12 Stancor A-3877 output Xformers, 12 2-gang tuning condensers, 46 NE-51 Neon bulbs, 50 NE-51 sockets and mountings, 24 12AX7 tubes, 24 9-prong tube sockets, $80. Lucien R. Janelle, 7 Parent Ave., Biddeford, Me.

FOR SALE — Hertner projection TV with 630 circuit, 20 w. Hi-Fi audio and 36" by 27" screen; Eico 360 sweep gen., $20; RCA WV-65A VTVM, $25; SX28 with speaker, $110. J. Wasiewicz, 74 Canterbury Rd., White Plains, N. Y.

SELL OR TRADE — Sprague Kwik-Test capacitor checker, model KT-1, operating manual included, $30, or trade for good bar generator or yoke and flyback tester. J. P. Torre, 143 Cornelia St., Brooklyn 21, N. Y.

FOR SALE — 250 w. Bassett police transmitter, exc. cond., modified to work all amateur bands, grey 66½" relay cabinet, 4 illuminated meters. Reasonable. Howard Vanderwal, 325 Franklin St., Grand Haven, Mich.

FOR SALE — Riders 22, $15; Log Log Duplex trig K&E slide rule with case, $10; Dietzgen "Commander" drawing set, $15, all good cond. Want used comm. receiver. Clyde Watts, 1201 Main, Wayne, Neb.

SELL OR TRADE — 2-meter converter (broad-band), ¾ meter trans. and rcvr., S20R, QST's 1927-1948, CQ's 1947-1951, Weston photocell, trans. tubes. Want autos, lamps, horns, license plates before 1915. Bob Schill, 1400 Poulson St., Wantagh, N. Y.

FOR SALE — Western Electric 618-A Dynamic Mike with plug and boom suspension bracket, $35. J. Cermak, 542 Woodside, Hinsdale, Ill.

TRADE — Elmac A54H mobile transmitter with dynamotor and Electro-Voice 600D mike, for model 12 teletype with keyboard. Will trade only for teletype equip. Henry A. Galbraith, 1101 East Franklin, Evansville 11, Ind.

WANT — Riders TV manuals 8, 10-12, also some as is TV receivers, local. For sale — few working televisions, Eico Deluxe sig. and sweep gen., 1. n. Charles Spitz, 1420 S. Randolph St., Arlington 4, Va.

FOR SALE — Radio City tube tester, model 310, $12; AC-DC-phono motor, 78 RPM, $8; 5 tube Arvin radio, $10; used car radio in exc. cond., $15. J. Kramer, 229 East 7th St., New York 9, N. Y.

FOR SALE — Phone patch with two cords and plugs. Satisfaction guaranteed, $4 postpaid in USA. Epps Griffin, Box 1074, Mt. Pleasant, Texas.

FOR SALE — Complete NRI radio, TV, FM amateur course, includes fone and 30 w. transmitter, multitester, wavemeter, mike, power supply, experiments, and kits, $100. Agostino, 223 So. Winebiddle Ave., Pittsburgh 24, Pa.

FOR SALE — Riders manuals, vols. 2-15 in good cond. with index, $85. Melvin Saur, Kent City, Mich.

TRADE — Complete dark room equip. (solar enlarger, etc.), for comm. receiver or other radio gear. Also have rifles to trade on radio receivers. Prefer local. Edward A. Muller, 1436 East 28th St., Brooklyn, N. Y.

SELL OR TRADE — Hallicrafter S58 AM-FM-phono in good cond., and portable Zenith 1953 radio, for tape recorder, or binoculars. Emory Corron, 4096 Redonda Lane, Dayton 6, Ohio.

SELL OR TRADE — Remington model 141 Game Master gun, for cash, Hi-Fi equip., typewriter, or test equip. Peter Guglielmo, Box 7174, Tuscon, Ariz.

WANTED — Small discarded table radios. Will buy or trade for portable typewriter, adding machine, 35 mm. camera, 16 mm. movie camera, art movies. E. Bridges, 217 Lineberger St., Shelby, N. C.

FOR SALE — Sams Photofacts, 1 to 30, filed in 2-drawer metal cabinets, $40; Riders, 1 to 20; Weston model 772 analyzer, $40; Chicago pocket VOM, $12.50. Neo, 4528 Milwaukee Avenue, Chicago 30, Ill.

WANTED — Jan. '54 issue of Radio-TV Service Dealer. State price. Harry Wendt, 1131 Craig Rd., Maumee, Ohio.

WANTED — Line cord for Crosley portable radio, model 27, or entire radio, priced cheap, old Firestone table model radios, Weston 772, any cond. Saxton's Radio, Route 1, Pontiac, Ill.

FOR SALE — Radio service shop, 4-room house, 3 lots, '36 Pontiac coupe with mounted Tristao crankup mast, hand tools, instruments, model 175M Sylvania 21" TV, etc. — the works for $7,500. Wallys Radio Service, Eureka, Mont.

SELL OR TRADE — 12 vol. encyclopedia; 35 mm. color camera, lens speed 2.8, for TV service instruments. Also trade Windsor clarinet for portable radio or record player. Larson's Radio Service, Madison, Minn.

SELL OR TRADE — Granco UHF converter, 1.n., originally $29.95, for best offer, or for signal generator. G. C. Van Dyke, 592 Funderburg Rd., Fairborn, Ohio.

SELL OR TRADE — NRI Radiotrician text for $50 or good hand printing press and supplies. Lowell P. Tyler, 85 Lincoln St., Dover-Foxcroft, Me.

SELL OR TRADE — Used 10", 12", TV sets; radios for '38, '41 Buick, and '40 Pontiac, for typewriter or adding machine. Harold's Radio Service, Morocco, Ind.

SWAP — Anemotherm air meter, replacement cost $250, in like new cond., for SX71 or equal. A. J. Goralski, 2414 South 29th St., Omaha, Neb.

WANTED — BC-654 receiver and transmitter unit with PE 104 or receiver alone. State price and cond. Sam W. Freeman, 201 East Oak St., Oxford, Ala.

TRADE — Tape recorder head; 78 RPM prayer head; Navy surplus radar outfit, for Riders manuals from 13 up, and complete CREI Engineering course in A-1 cond. Warren J. Currence, 200 Diamond St., Elkins, W. Va.

WANTED — Motorola model CTO or CT-9 or Philco 505 or any other radio to fit inst. panel of '50 Chevrolet. Condition not important. W. Kemper, 825 NW 149 Tr., Miami 50, Fla.

WANTED — Hallicrafters portable S-29 and S-39, for cash. Will sell Scott All-Wave 15 and Meissner FM tuner, also pilotuner. David Stutson, 950 Columbus Ave., New York 25, N. Y.

SELL OR TRADE — Radio and TV parts for 8 mm. films. What do you need? Vincent Malack, 10530 Edbrooke Ave., Chicago 28, Ill.

SWAP — B&W CX 95-C butterfly condenser with neut. plates and HDVL 20 coil assembly, also 813 tube. Need wide angle lens for Argus C-3 camera. M. Katz, 147-11 76th Ave., Flushing 67, N. Y.

SELL OR TRADE — 328 radio magazines, send offer for details. Want heavy duty battery charger or test equip. You pay freight. J. T. Kelly, 778 W. 7th St., San Pedro, Calif.

FOR SALE — Howard Sams Vol. 1 (in binder, 1 to 10 Photofact sets), sets 11 to 39 incl., and 42. Very little used, A-1 cond., $35 plus postage. Joseph J. Ellis, 1818 Price St., Scranton 4, Pa.

FOR SALE — Riders manuals, in exc. cond, abridged edition 1-5, 6-11, 13 and index. Will sell for best offer. Howard F. Palmer, 507 Spencer Rd., Ithaca, N. Y.

BUY OR SWAP — Radio and TV tubes for Sylvania model 140 or any good roll chart type tube tester. Have 8" and 17" Rauland Pix tubes. Andrews, 740 Maple St., Bethlehem, Pa.

TRADE — Regency TV sig. booster, 3-2525, 3-27, 4-35/51 — all new tubes, Wright cooler, for 10 w. or more amp. with record changer or scope or complete PA system. M. J. Castro, 1300 E. San Antonio, El Paso, Tex.

WANTED — Job for Saturdays and evenings to learn the radio-TV field: test equip., selling, repair, etc. Am NRI grad. Services will be free. Prefer to work for NRI graduate. John Graf, Moline, Ill.

WANTED — Riders and Sams manuals. State volumes and price. Floyd Nave, 66 Forward St., Bakersfield, Calif.

FOR SALE — RCP sig. gen., $14; Clough-Brengle sig. gen.; Eico VTVM, $19; Royal office typewriter, $21. All in good working order. P. Coffey, 2623 Halperin Ave., Bronx, N. Y.

SELL OR TRADE — National HFS receiver with National power supply and speaker in excellent condition, $99; or will trade for printing press and supplies. P. Zukauckas, 4862 Mass St., Gary, Ind.

FOR SALE — ATR inverter, DC to AC, 110 v. input and output, 500 w. capacity, in good cond., $37. L. Uckerman, 6 Fernboro St., Roxbury, Mass.

SELL OR TRADE — 7" Motorola TV booster, tubes, for rifle scope, voltohmmeter or cash. Thomas Rohland, RR 3, Martinsville, Ind.

FOR SALE — Radio and television store, fully equipped, good business section, reasonable rent and long lease. Price reasonable. George Dexter, 779 - 8th Ave., New York, N. Y.

FOR SALE — Presto 15g turntable, Clarkstan 213 pick-up arm and needle gauge, Astatic FLC pick-up arm with diamond stylus 78 RPM crystal cartridge, Shure 710 crystal mike, etc. J. R. Holloway, 1421 Arch St., Philadelphia 2, Pa.

SELL OR SWAP — Presto-K-10 professional type recorder, several blanks, sapphire cutting needles, $366.50 net. Swap for new Johnson-Viking II transmitter kit or equivalent. Chas. R. Graff, 6640 Edmund St., Philadelphia 35, Pa.

FOR SALE — BC 454-B 3-6 Mc. surplus receiver, never converted, with diagram and conversion data, $5; Vision TV UHF booster preamp in new cond., has 2 6AKS's, $4. Seymour Tenzer, 88 Van Sicklen St., Brooklyn 23, N. Y.

WANTED — New or used (in exc. cond.) barrel for Tokarev 7.62 mm. automatic (Russian). Will swap amateur radio gear, receiving or Xmtr. tubes, etc. Name your needs. Louis Welsh, R 6, Kokomo, Ind.

FOR SALE — L. n. RCA 152-174 Mc. mobile transmitter-receiver, 30 w. output: Type CMV-4B (12.6 v. DC) with tubes, cables, antenna, and control head. In orig. shipping cartons, $300 FOB. Dick Heintzelman, 3429 Market St., Camp Hill, Pa.

SWAP — Stamps for surplus radio equip., parts and tubes. M. Smith, 3534 1st Ave. N.E., Cedar Rapids, Iowa.

FOR SALE — Heathkit 03 scope and Heathkit S-1 electronic switch, both wired, complete, little used, excellent cond. Both for $39. H. M. Lester, 101 Park Ave., New York 17, N. Y.

WANTED — Scott tuner chassis, power chassis, speaker networks, and speakers for 33-tube Philharmonic AM-FM, or complete set. Also, power chassis, speakers and network, for Phantom Deluxe 28 T. Scott. Please contact — cash or trade. Woddies Fixit Shop, 1709 E. Stella, Fort Worth 4, Texas.

TRADE — Approx. $50 in HO train equip. and $60 worth of stamps in plate blox of 4, ordinary blox of 4 and ship covers, for Comm. receiver, or portable typewriter. J. L. Briggs, 1957 Granito Vista, Tucson, Ariz.

WANTED — Panadaptor; BC-453 (unmodified); QST prior to 1923; bound volumes CQ. State cond., and price. F. M. Kern, 408 East Wynnewood Road, Wynnewood, Pa.

FOR SALE — Heath RF sig. gen. model SG-7, never used. Mail to any part of U.S. for $20. R. A. Staib, 1621 North Avers, Chicago 47, Ill.

FOR SALE — Radio Comm. receiver, by Karr Engineering Co., Palo Alto, Calif., Type KE23AT, 4 bands, 8 tubes, built to Army specifications, A-1 cond., phonojack, speaker, cut-out added. Courtney Porter, Box 168, Hanover, N. H.

SELL OR SWAP — Regency converter, model RC-600, $30, for E200C; U2 RCA converter, for 6 v. 10 amp. eliminator, SX42 R42 speaker, Harvey Wells, deluxe, plus cash. Floyd Bitters, Route 2, Peoria, Ill.

TRADE — Back issues, Radio News and Service magazines, also several international textbooks on radio subjects, for empty .270 cal. cases in good cond. Edward C. Dobson, 32 Oliver St., Central Park, Penns Grove, N. J.

FOR SALE — Dumont 3" scope, model 164E, exc. condition, $35. Mrs. I. J. Burzynski, 39 Crosby Ave., Brooklyn 7, N. Y.

FOR SALE — Stancor ST-203-A 10M mobile transmitter, $28; Electro-Voice model 600-D dynamic mike, with push-to-talk switch, $15; power supply 400 v. at 200 Ma., 6.3 v. at 5 a., $12. Leon Berandt, 621½ Brooks St., Ann Arbor, Mich.

FOR SALE — One-tube code oscillator, 110 v. AC-DC, can be used with phones or small PM speaker, $5. Leonard Weiss, 104 Palmer Ave., Stamford 35, Conn.

FOR SALE — Rig: 150 w., MB 150 10-80 meters, TVI proofed (B&W 75A), modulator (incomplete), power supply; 800 v. 300 Ma., 350 v. 200 Ma., S40A receiver, all for $125. Paul Greenberg, 757 East 179th St., Bronx 57, N. Y.

TRADE — Model motors and some model equip., for test equip., radios or parts and tubes. Any reasonable offer. E. A. Sawyer, Box 346, Marshall, N. C.

WANTED — Test equip., such as Precision E200C sig. gen., Eico or Heathkit RF and sweep gen., probes, etc. Also a Standard Cascode tuner and books on test equip. and servicing. Irving J. Rohssler, 224 York St., Brooklyn 1, N. Y.

FOR SALE — Superior 670A VOM-Capacitance-Inductance meter, 1. n., $17.50; Eico sweep gen., $20. E. M. Beals, 3536 Colonial St., Corpus Christi, Texas.

FOR SALE — Two Eimac 100th's, less than 100 hrs. use, $15. F. A. Mitchell, 140 E. Elisha St., Waterloo, N. Y.

TRADE — Two Meissner 8C FM tuners, exc. cond., and Edwards Fidelotuner, for portable typewriter. Wm. H. Jones, Jr., 13 - 18th St., Greer, S. C.

FOR SALE — Jackson TV-FM-sweep sig. gen., model TVG-1 in A-1 cond., $100. Victor LeBeau, 3616 - 42nd Avenue North, St. Petersburg, Fla.

WANTED — Hallicrafters model SX-28A receiver, must be in good operating cond. on all bands. Prefer local cash deal. Harry Bianchini, 440 Grand Ave., Oakland 6, Calif.

SELL OR TRADE — ½" industrial drill, small hand tools, watchmakers bench, tools, radio parts, etc. Want Heath or Eico battery eliminator, charger, or other Heath instruments. Alfred Kenna, 2200 Hamilton Ave., No. Merrick, L. I., N. Y.

FOR SALE — Complete technical library, 24 texts, list furnished on request. Proceedings of IRE, June, '49 thru June, '51, "Electronics", McGraw-Hill, 1949 thru April, '54, QST, 1951 thru July, '53. M. Jetit-Clerc, 14 Parsons Drive, Beverly, Mass.

FOR SALE — 3 Jewell meters; Solar cond. tester, model QC, $7.50; "B" eliminator; Majestic power pack. W. E. Randall, 264 Sayford St., Harrisburg, Pa.

FOR SALE — Knight "Ocean-Hopper," wired, broadcast and 2.9 - 7.3 Mc. coils; phones; E. F. Johnson key, 114 - 321; "First Principles Radio," Oxford Book Co., 1953 handbook, 1954 license manual. Best offer. Harry Moses, 3907 Ventnor Ave., Atlantic City, N. J.

SWAP — Latest set British-Honduras mint stamps for small, portable multitester, or ham gear. William Williamson, 7 Collett Canal St., Belize, British Honduras, Central America.

FOR SALE — Precision tube and set tester, model 10-54, $100; Emerson model 646 3-way radio, $15. J. LoCascio, 108-50 39th Ave., Corona 68, N. Y.

FOR SALE — Hallicrafter S20R, fine cond., $45; Echophone Commercial Comm. rcvr., model EC-1A, fair cond., $15; Lincoln Engineering School radio and electrical course, 42 volumes, $15. Joseph DiTucci, 234 Parkway, Rochester 6, N. Y.

SWAP — Hickok 288X in exc. cond., for 610A Hickok sweep gen., also need scope. Radio TV Service, 1751 Georges Lane, Philadelphia 31, Pa.

FOR SALE — National NC-57 Comm. rcvr. Has BFO, AVC, bandspread, voltage regulator tube., exc. cond., $40 FOB. James P. Youngren, 422 Gregory, Rockford, Ill.

WANTED — Electronic flash unit or components, Sprague FF-1 condensers, new flash tubes, good enlarger. Will sell or swap, 35 mm. Super Baldina, coupled rangefinder, f2.9 lens. Paul Woliner, 1149 Tiffany St., Bronx 59, N. Y.

FOR SALE — Unused Super Aerotrol 27. 225 Mc. radio control, including: Xtal. controlled trans., rcvr., whip antenna, tuning meter, operating instructions. Best offer over $25 takes all. J. McLeland, 600 N.E. 26 Terr., Miami, Fla.

FOR SALE — ARC 5 VFO for 40 meter C.W. with AC power supply, has been given T-9 reports on signal. Make offer, prefer local sale. Herbert Paskin, 1402 Brooklyn Ave., Brooklyn 10, N. Y.

WANTED — UHF converter, good operating cond., cash, must be reasonable. A. H. Davis, 2585 Sylvan Rd., Cuyahoga Falls, Ohio.

FOR SALE — A54H Elmac; power supply (PS-2V model) for Elmac; model 55 Shure Unidyne. Local sale, best offer. E. Bowley, 31-19 43rd St., Long Island City 3,N. Y.

FOR SALE — Heathkit scope, model 0-5 in perf. working order, $22.50. Latham Radio Shop, Cuba City, Wis.

WANTED — Job as a TV technician, have completed training and have had four and a half years experience. Very good references. Austin Berkebile, 305 Fair Ave., Johnstown, Pa.

FOR SALE — National NC-108 FM receiver, in perf. cond., $50 FOB. Service manual included. Robert Broadwell, RFD 1, Cadyville, N. Y.

FOR SALE — Like new Scott 112B Dynaural pre-amp noise suppressor, $40; Alliance BB-2 Cascamatic TV booster, cartoned, $9; G.E. automatic stabilizer 69G869 95 - 130 v. input, 115 v. output, new cond., $11. What have you? Frank Damico, 86 - 75 Midland Pky, Jamaica 3, N. Y.

WANT — 1950 Ford auto radio, good cond. State price. Will sell Exakta camera, 3.5 lens focal plane shutters, for what have you. Albert Ferrito, 334 Lincoln Ave., Brooklyn 8, N. Y.

WANTED — Geiger counter and 5 x 7 or 8 x 10 view camera and or lenses. Have cash, or 10" RCA ST630 TV, misc. items. Irving Pavey, 1242 So. Kedvale Ave., Chicago 23, Ill.

TRADE — Viking I and VFO and pay difference for "More Power", or will buy Hi-power for cash if a bargain. Fred Rudolph, Box 516, Stryker, Ohio.

WANTED — Scope, Heathkit 0-7, or Eico, in good cond. Subject to prior inspection only. S. Consalvo, 4905 Roanne Drive S.E., Washington 21, D. C.

WANTED — Late model Heathkit scope and TS-3 sweep gen., in good cond. Will sell or trade Electro-Voice TV booster in orig. carton. Value $57.50, make offer. Irv's Electric Shop, Ingalls, Kan.

SELL — G.M. Diesel gen., 110-220 v. AC, 60 cycles, 10 Kw., exc. cond.; Eicor tape recorder, 1. n.; Sams folder vol. covers, 1. n., $2.25 each, 10 for $20; portable power megaphones, $25. John Graham, Box 68, Wurtsboro, N. Y.

FOR SALE — Harvey Wells APS-50 power supply, never used, $35; Heineman 115 v. 4 amp. AC circuit breakers; DM-49-AX 12 v. input, 500 v. @ 400 Ma. output; Signal Corps converter. Want schematic diagram for Echophone model EC-3 comm. receiver. Don Parker, 75 Lewis Ave., Brooklyn 6, N. Y.

FOR SALE — Riders 1 to 16 radio manuals, l. n., $80 FOB Los Angeles. Dick Sexton, 815 Violeta Dr., Alhambra, Calif.

WANTED — Wire recorder in good cond. Must be bargain-priced. Walt Bartell, 1107 North Western Ave., Chicago 22, Ill.

SELL OR SWAP — RCA "Cascode" 40 Mc. tuners, latest type, unused, uses 6BQ7A and 6 x 8 less tubes, $15 each, or ?? C. Elgasser, Jr., 1920 Fern St., San Diego 2, Calif.

WANTED — NC100 ASO, or SX24. Will pay cash, or trade test equip., etc. T. Ferguson, 171 East 91st St., New York 28, N. Y.

WANTED — Will pay cash for condenser and resistor checker. State price and cond. Luke Strader, 1217 Myrtle Ave., Danville, Va.

WANTED — Hookup data on use of surplus sonar underwater detection unit with 3-white and 1-black input wires. Useless without info. Will give a 3-speed motor and 8" turntable. J. Verzi, Jr., Brucetown, Va.

FOR SALE — Dumont 304 oscilloscope, excellent condition, $180. Alex Siegel, 1516 Shakespeare Ave., New York 52, N. Y.

WANTED — E200C Precision sig. gen., in good cond. Mimna TV, 271 No. 6th St., Newark 7, N. J.

WANTED — Christy trade school appliance course, late issue for cash. State cond. and lowest price. David Friedman, 1562 East 16th St., Brooklyn 30, N. Y.

FOR SALE — Prop-Pitch motor, heavy duty type, partially converted, $12.50 FOB. C. B. Kelley, 7204 Clovernook Ave., Cincinnati 31, Ohio.

SELL OR TRADE — Portable phonograph, wind-up type, fine tone, $7. Y. Brerda, 55 Hanson Place, Brooklyn 17, N. Y.

FOR SALE — Sun CR-10 Triode amp., $50; Garrard RC-65 2-speed record-changer, GE pickup, $15; Speco 3-mike mixer, $8; Astatic JT-30 mike, $7; Amperite SKH Contact mike, $4.50. Donald P. Bargen, 418 Gregory, Rockford, Ill.

FOR SALE — Precision tube checkers, models 900 and 915, $20 and $40; RCA 10" TV table type, $40; Jackson Universal oscillator 5 bands, $60; VTVM with leads, $25. Or best cash offer. John Pellock, 815 W. Washington, Springfield, Ill.

SELL OR TRADE — Meck T60-1 with coils 160 thru 10 meters; VX101JR VFO, both in A-1 cond. Make offer. R. T. Whitaker, Bishop, Texas.

FOR SALE — Simpson tube tester, model 555, 10 months old, l. n., $60. John D. Pavlic, 907 Rebecca St., McKeesport, Pa.

SELL OR SWAP — Presto K8 disc recorder with lightweight dual stylus cartridge, and arm, $130. Need scope with DC amps. or an AM-FM tuner, (no kit equip.). Carl T. Petersen, 2430 East 20th St., Oakland 1, Calif.

FOR SALE — Jerrold TV antenna system with 7 antenna distribution outlets, for 16 receivers. Write for price. Soundcraft Products Co., 9 Kelley Square, Worcester 4, Mass.

FOR SALE — Tape recorder (A.C.A. Twintrax) 1 hour uninterrupted 10,000 cy. recording at 7½ i.p.s., $50 in accessories included. Appearance l. n., operation perfect. Best offer over $200. M. A. Garr, 33 Whisper Lane, Wantagh, N. Y.

FOR SALE — RCA sig. gen., six alignment ranges, 100 Kc. to 30 Megs., with instruction book. $25 if called for. H. Latko, 1922 Dickens, Chicago, Ill.

WANTED — UTC VM-4 modulation transformer in exc. cond. State price. Earl C. Abbott, Manahawkin, N. J.

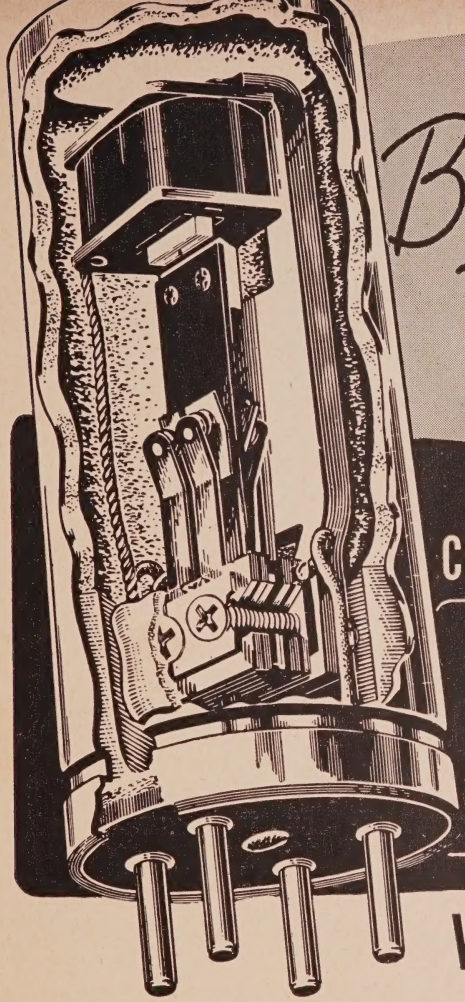
WANTED — Cash for complete Hi-Fi system or trade almost new wire recorder; also want "How to Do It" books and magazines. J. T. Wentworth, 106 S. Dearborn St., Mobile, Ala.

FOR SALE — Motorola Vibrator T69-20A, 6 v. input, output 340 v. @ 240 Ma., two units in parallel, $22. Anthony Brocato, 699 Idlewild Circle, Birmingham, Ala.

SELL OR SWAP — Good 5-tube amplifier, 12" speaker, wooden cabinet. Swap for good spinning reel with full bail, such as Ocean City or Mitchell, etc. John R. Potter, 112 Paul St., Sayre, Pa.

FOR SALE — HQ129X with speaker; DB 20; Eico 425 scope; 700 v. 200 Ma. power supply; Instructograph; Ameco code records; Code osc. WSAS1, 114 - 34 72 Dr., Flushing 67, L. I., N. Y.

FOR SALE — Heathkit 0-9 scope, $60; Heath VC-2 voltage calibrator, $10. Both in perf. condition. Paul Richter, 1446 Webster Ave., Bronx 56, N. Y.



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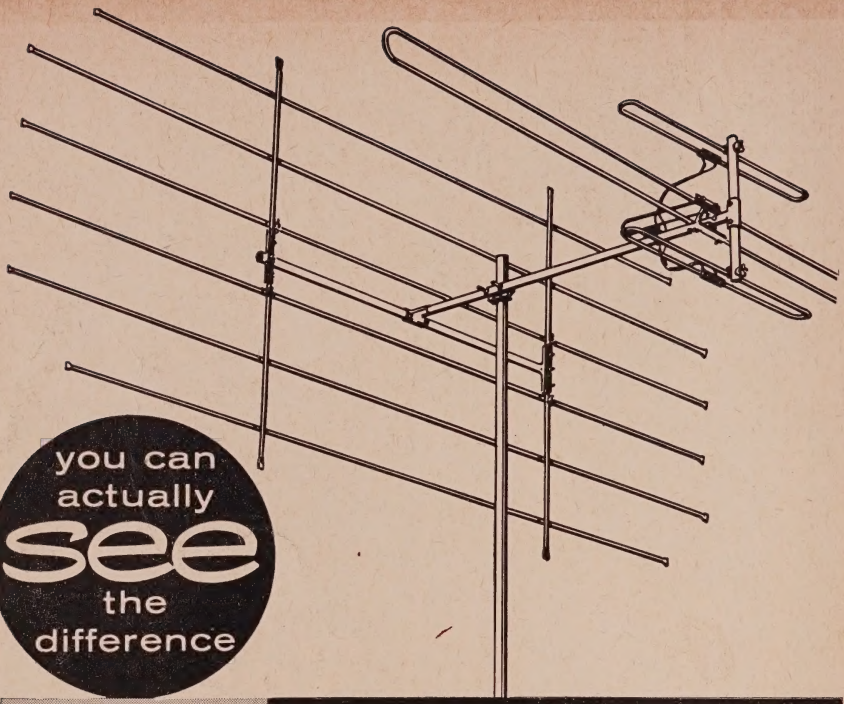

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All Channel TV Antenna

NOW... C-D designs the finest TV Antenna... the first antenna with which you can actually SEE the difference! Perfectly synchronized for monochrome *and* COLOR TV. The most uniform gain response that does not vary more than 3 D.B. on any channel across the band. Other features include low voltage standing wave ratio... higher front-to-back ratio... speedy assembly... aluminum screen reflector... dipole and boom of heavy gauge, seamless tubing.

Consistently Dependable

CORNELL-DUBILIER

SOUTH PLAINFIELD, N. J.

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